Chapter 9

Arm: Humerus, Radius, and Ulna

The limbs of terrestrial vertebrates (tetrapods) are secondary adaptations of structures — paired fins — that were originally adapted for life in an aquatic habitat. The first vertebrates were jawless fish (Agnathans) — animals similar to modern lampreys and hagfish — which had a rudimentary axial skeleton, but lacked both jaws and paired fins. Jaws and fins evolved about 400 million years ago, allowing fish (the Gnathostomes) to locomote and feed more effectively. These early jawed fish had two sets of paired fins (a pair each of pectoral and pelvic fins) connected to flat plates of bone that were attached to the muscles of their body walls. These paired fins, flexible fans of small bones, are still seen in modern fish, which use them primarily as aids for stabilization and steering. Limbs evolved from this structural arrangement as fins were gradually co-opted for use as load-bearing appendages by early tetrapods. Although the limbs of land vertebrates seem very different from fish fins, the two homologous structures are actually highly comparable.

Each vertebrate limb has a base and three segments. The limb girdles (the pelvis for the lower limb and the scapula and clavicle for the upper limb) are the old basal fin plates of fish, which evolved to take on the function of transferring the weight of the body to the limbs of the terrestrial tetrapod. The proximal vertebrate limb segments constitute the upper arm and thigh. The intermediate limb segments, the forearm and foreleg, each comprise two bones in humans: the radius and ulna in the arm, and their serial homologs, the tibia and fibula, in the leg. This chapter examines the three bones of the two proximalmost segments of the upper limb: the humerus, radius, and ulna.

9.1 Humerus (Figures 9.1–9.8)

9.1.1 Anatomy

The upper arm bone, or **humerus**, is the largest bone in the upper limb (arm). It comprises a proximal end with a round articular head, a shaft, and an irregular distal end. The humerus articulates proximally with the glenoid fossa of the scapula and distally with both the radius and the ulna.

a. The **humeral head** is a hemisphere on the proximal end of the humerus that faces medially and articulates with the glenoid fossa of the scapula.

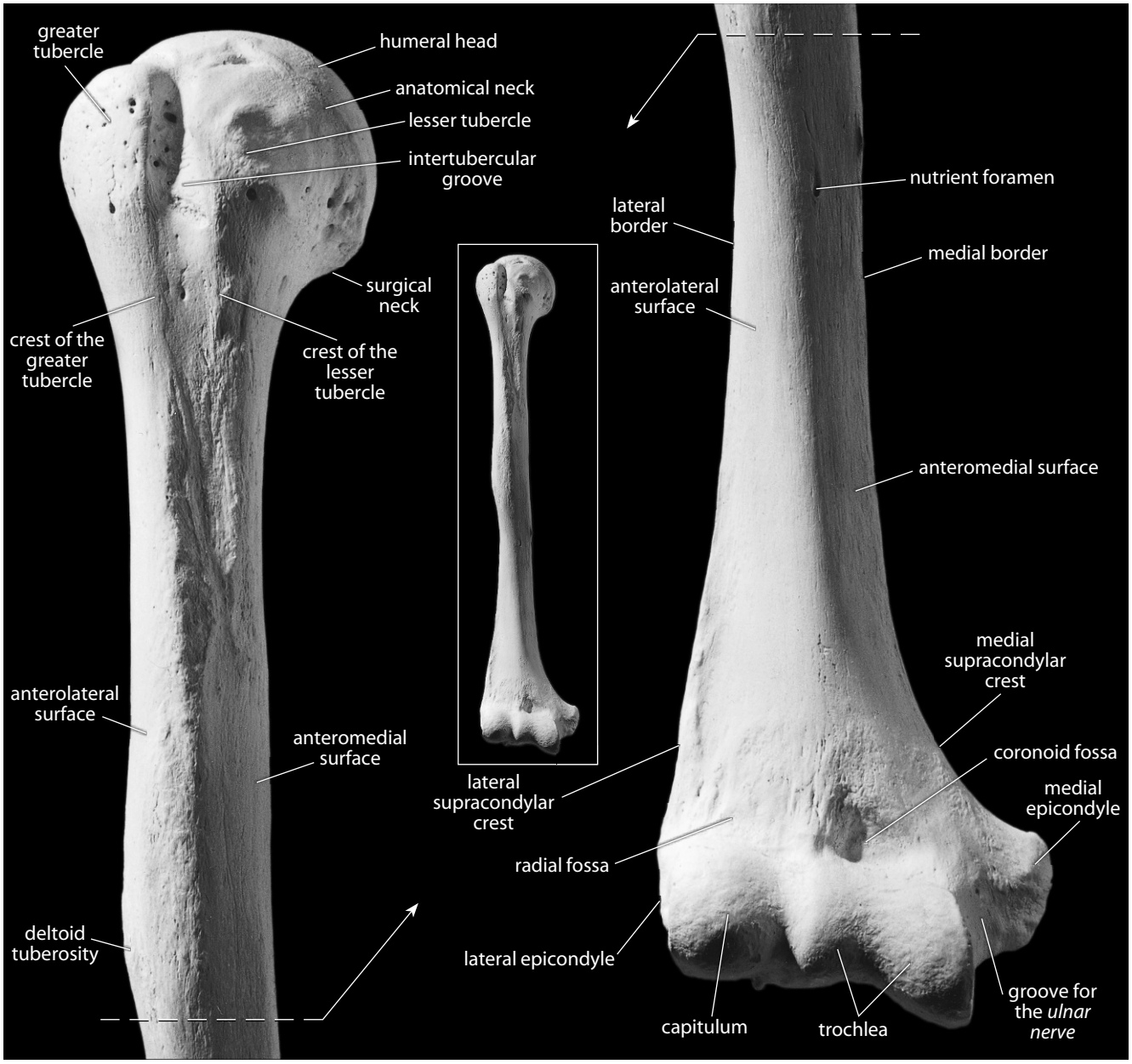

Figure 9.1 **Right humerus, anterior.** *Left:* proximal portion; *right:* distal portion. Natural size.

b. The **anatomical neck** is the groove that encircles the articular surface of the humeral head and marks the area of the attachment of the *joint capsule*.

c. The **surgical neck** is the short constricted segment inferior to the head. It links the head and shaft.

d. The **lesser tubercle** is a small, blunt eminence anterolateral to the head on the proximal shaft. The lesser tubercle marks the insertion of the *subscapularis muscle*, which originates on the costal surface of the scapula and rotates the humerus medially.

e. The **greater tubercle** is larger, more posterior, and projects more laterally than the lesser tubercle. The greater tubercle bears rugosities for the insertion of the *supraspinatus*,

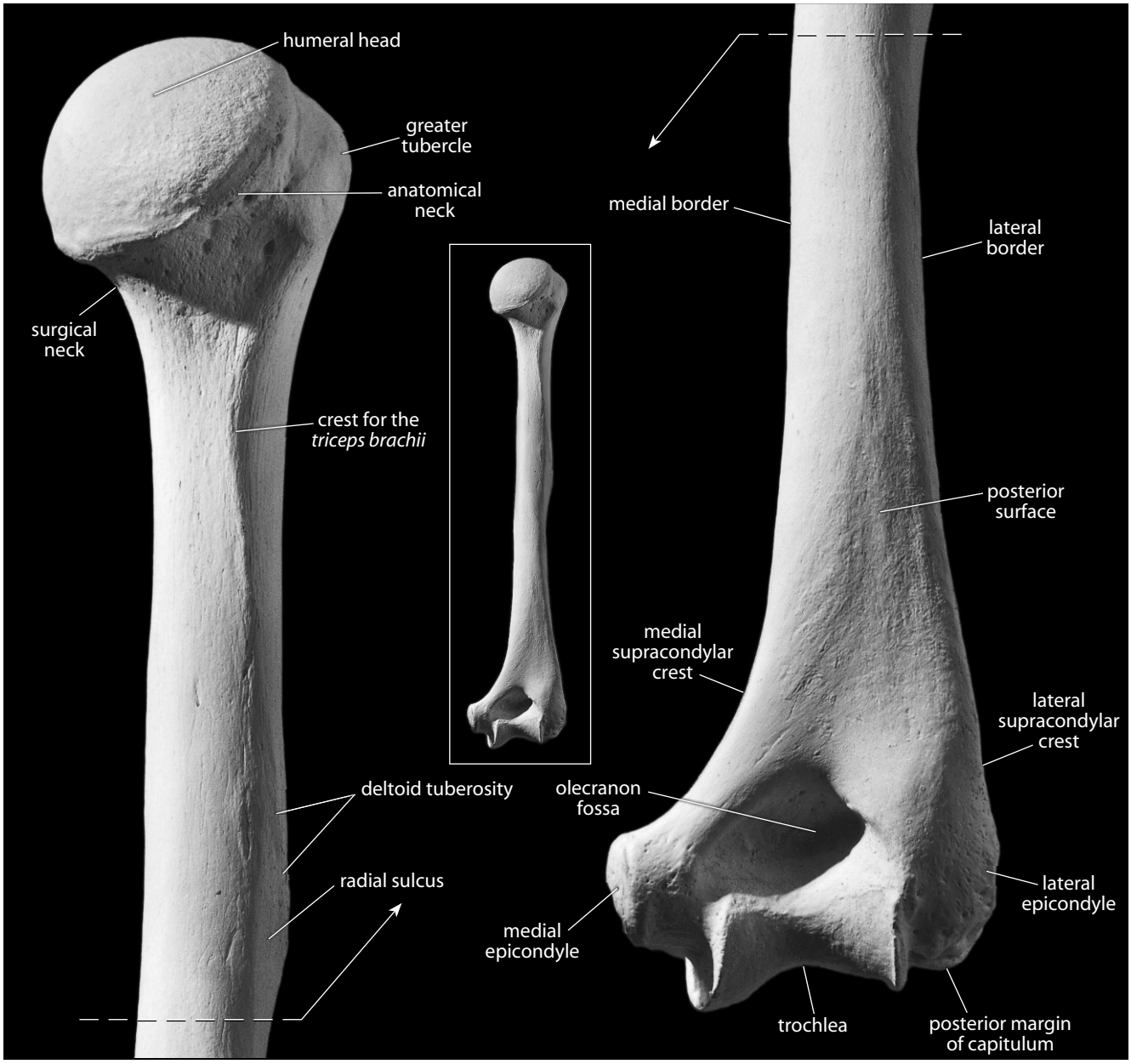

Figure 9.2 **Right humerus, posterior.** *Left:* proximal portion; *right:* distal portion. Natural size.

infraspinatus, and *teres minor muscles*. These muscles, together with the *subscapularis muscle*, constitute the *rotator cuff muscles*. In addition to medial and lateral rotation, these muscles also aid in adduction and abduction of the arm.

f. The **intertubercular groove** (or **bicipital sulcus**) extends longitudinally down the proximal shaft. It begins between the two tubercles and houses the tendon of the long head of the *biceps brachii muscle*. In life, the *transverse humeral ligament* connects the two tubercles to bridge the groove and form a canal.

g. The **crest of the greater tubercle** forms the lateral lip of the intertubercular groove. It is the insertion site for the *pectoralis major muscle*, a muscle that originates on the anteromedi-

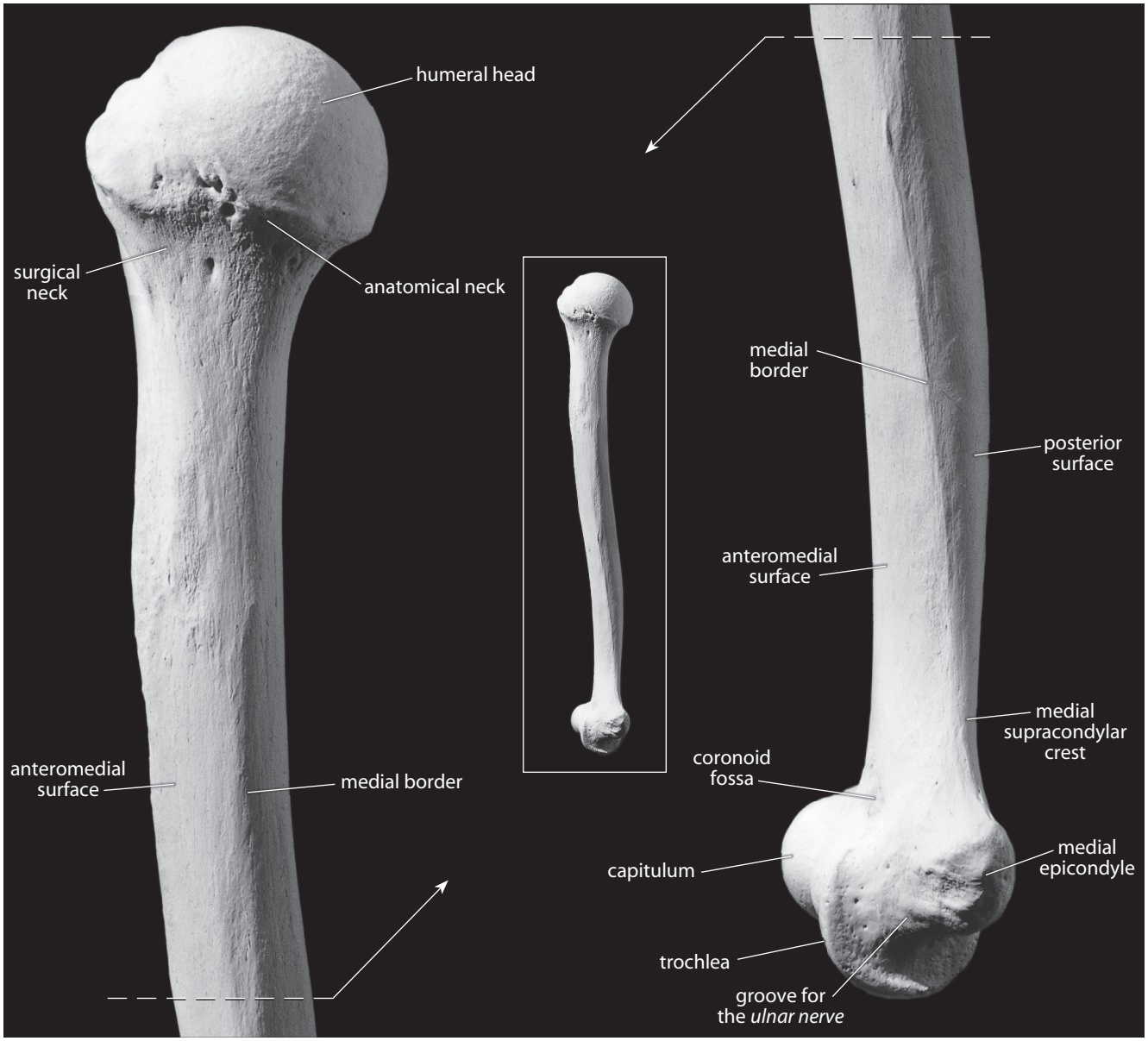

Figure 9.3 **Right humerus, medial.** *Left:* proximal portion; *right:* distal portion. Natural size.

al clavicle, the sternum, and the cartilage of the true ribs. This muscle acts to flex, adduct, and medially rotate the arm.

h. The **crest of the lesser tubercle** forms the medial lip of the intertubercular groove. It is the insertion site for the *teres major* and *latissimus dorsi muscles*, medial rotators and adductors of the arm.

i. The **humeral shaft** (or **body**) is variably triangular, ranging from more cylindrical in its proximal section to an anteroposteriorly compressed, rounded triangle distally (see cross sections in Chapter 14). The shaft is divided into three named surfaces.

j. The **anteromedial surface** is the portion of the shaft surface between the medial border and the continuation of the crest of the greater tubercle.

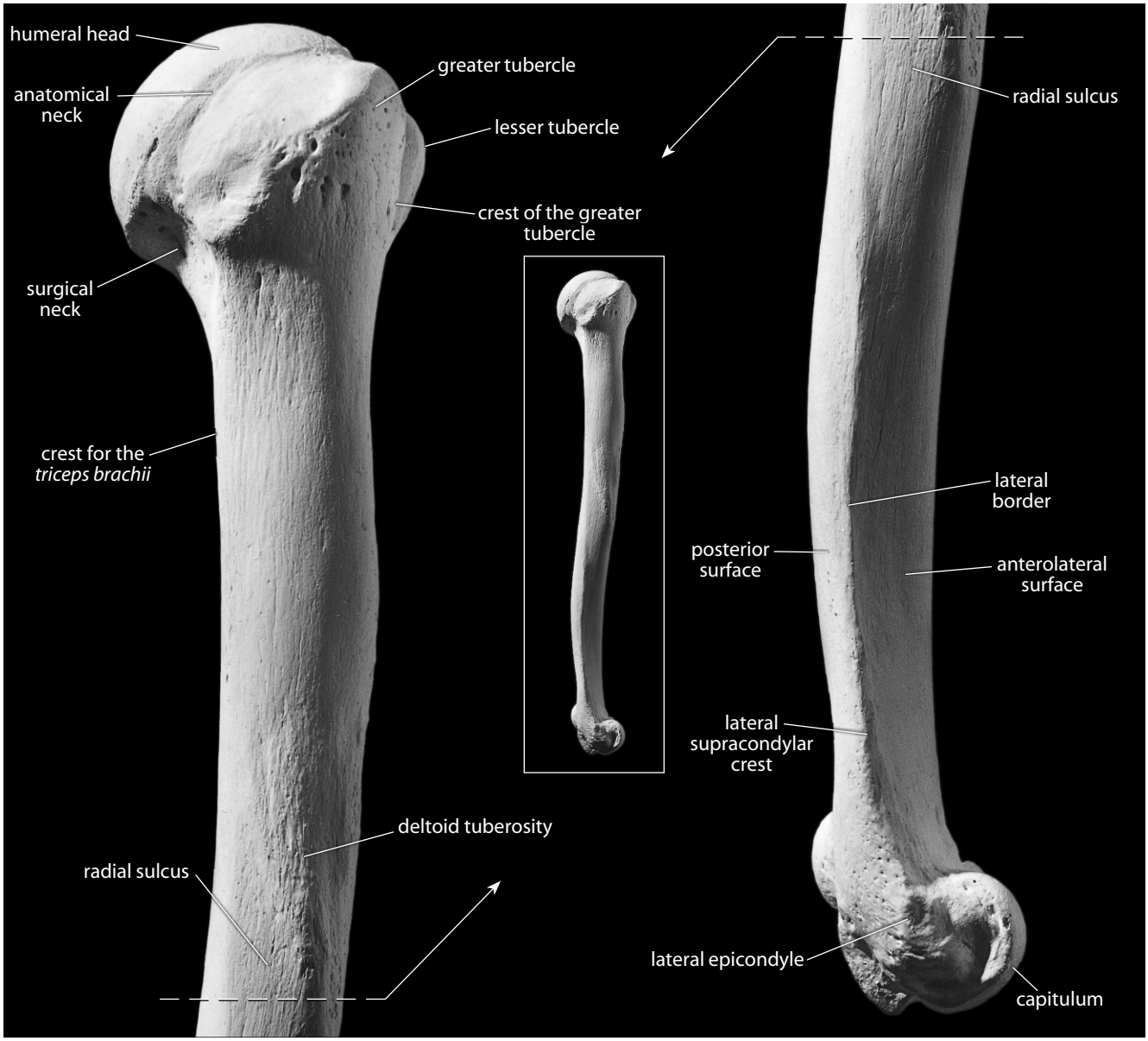

Figure 9.4 **Right humerus, lateral.** *Left:* proximal portion; *right:* distal portion. Natural size.

k. The **anterolateral surface** is the portion of the shaft surface between the lateral border and the continuation of the crest of the greater tubercle.

l. The **posterior surface** is bounded by the medial and lateral borders.

m. The **medial border** is continuous with the medial supracondylar ridge.

n. The **lateral border** is continuous with the lateral supracondylar ridge.

o. The **deltoid tuberosity** is on the lateral surface of the shaft. It is the insertion site of the *deltoideus muscle*, a major abductor (among other functions) of the arm that originates from the anterior border and superior surface of the clavicle, the lateral margin and superior surface of the acromion, and the scapular spine. The deltoid tuberosity is recognized by its roughened surface. It tapers to a V-shape on the lateral aspect of the humerus.

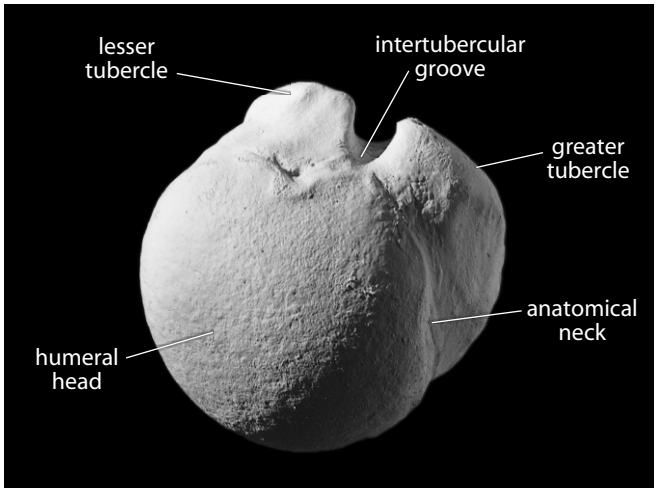

Figure 9.5 **Right humerus, proximal.** Anterior is up, lateral is to the right. Natural size.

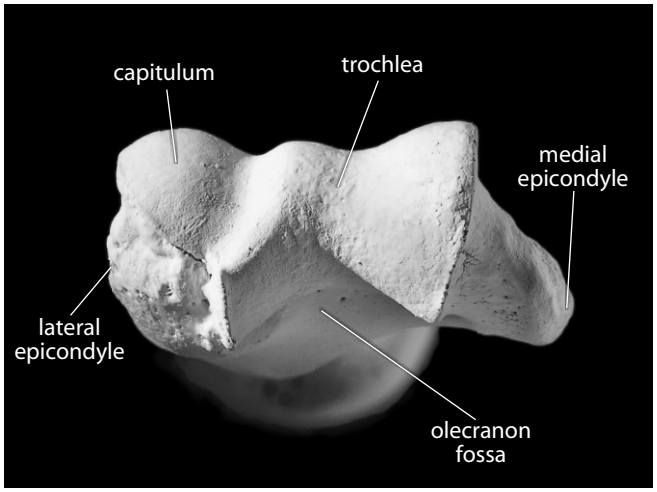

Figure 9.6 **Right humerus, distal.** Anterior is up, lateral is to the left. Natural size.

p. The **crest for the *triceps brachii*** is found on the posterosuperior shaft, beginning just below the surgical neck and extending inferiorly to the posterosuperior tip of the deltoid tuberosity. It provides a site of attachment for the lateral head of the *triceps brachii muscle*.

q. The **radial sulcus** (or **spiral groove**) is found on the posterior surface of the shaft. It is a shallow, oblique groove for the *radial nerve* and deep vessels that pass parallel and immediately posteroinferior to the deltoid tuberosity. Its inferior boundary is continuous distally with the lateral border of the shaft.

r. The **nutrient foramen** is located anteromedially and exits the shaft from distal to proximal. A good way to remember the direction of entry of nutrient foramina into all of the long bones is to imagine tightly flexing your own arms (at the elbows) and legs (at the knees) in front of you. In this position you can look into the bones via the foramina. In long bones, these foramina transmit the *nutrient arteries*.

s. The **olecranon fossa** is the largest of three hollows on the distal humerus. It is posterior, accommodating the olecranon of the ulna during forearm extension. The deepest area of this fossa is occasionally perforated, forming a foramen, or **septal aperture**.

t. The **coronoid fossa** is the larger, medially placed hollow on the anterior surface of the distal humerus. It receives the coronoid process of the ulna during maximum flexion of the forearm.

u. The **radial fossa** is the smaller, laterally placed hollow on the anterior surface of the distal humerus. It receives the head of the radius during maximum flexion of the forearm.

v. The **capitulum** is the rounded eminence that forms the lateral portion of the distal humeral surface. It articulates with the head of the radius.

w. The **trochlea** is the notch- or spool-shaped medial portion of the distal humeral surface. It articulates with the ulna.

x. The **lateral epicondyle** is the small, nonarticular lateral bulge of bone superolateral to the capitulum. It serves as a site of attachment for the *radial collateral ligament* of the elbow and for the common tendon of origin of the *supinator* and the *extensor muscles* in the forearm.

y. The **medial epicondyle** is the nonarticular, medial projection of bone superomedial to the trochlea. It is more prominent than the lateral epicondyle. It provides a site of attach-

ment to the *ulnar collateral ligament*, to many of the *flexor muscles* in the forearm, and to the *pronator teres muscle*.

z. The **medial supracondylar** (or **supraepicondylar**) **crest** (or **ridge**) is superior to the medial epicondyle and forms the sharp medial border of the distal humerus.

aa. The **lateral supracondylar** (or **supraepicondylar**) **crest** (or **ridge**) is superior to the lateral epicondyle and forms the sharp lateral border of the distal humerus.

9.1.2 Growth (Figure 9.7)

The humerus ossifies from several centers: the shaft, a compound proximal epiphysis, and a distal epiphysis. The compound proximal epiphysis is itself a composite of three centers of ossification: the head and both tubercles, all of which fuse together at 2–6 years. The distal epiphysis is composed of the capitulum and the lateral part of the trochlea, the medial part of the trochlea, the lateral epipcondyle, and the medial epicondyle. The capitulum, trochlea, and lateral epicondyle all fuse together at 12–14 years, before any of them fuse to the shaft.

The compound distal epiphysis fuses to the shaft first, beginning at about 12–17 years in males, and about 11–15 years in females. The medial epicondyle fuses next, beginning at about 14–16 years in males, and about 13–15 years in females. The last to fuse is the compound proximal epiphysis, beginning at about 16–20 years in males and at 13–17 years in females (Scheuer and Black, 2000).

9.1.3 Possible Confusion

The humeral head cannot be mistaken for a femoral head because the former is only half of a sphere, whereas the latter is substantially more than half.

- The femoral head has a distinct depression, or **fovea capitis**, that the humerus lacks.
- The humeral shaft is larger and more circular in section than the radial, ulnar, or fibular shafts (see cross sections in Chapter 14).
- The humeral shaft is smaller and more irregular in section than the femoral shaft (see cross sections in Chapter 14).
- The humeral shaft is smaller and less triangular than the tibial shaft (see cross sections in Chapter 14).

9.1.4 Siding

- For an intact bone, the head faces medially, the capitulum is lateral, and the olecranon fossa is posterior.
- For an isolated proximal end, the head is medial, and the lesser tubercle and intertubercular groove are anterior.
- For an isolated distal end, the olecranon fossa is posterior, the medial epicondyle is larger, and the capitulum is lateral and oriented anteriorly. If the articular end is missing, the coronoid fossa is larger and more medial than the radial fossa.
- For an isolated shaft fragment, the deltoid tuberosity is lateral, with its posterior arm passing from posterosuperior to anteroinferior, and the nutrient foramen exits the bone toward its proximal end. A small, thin ridge runs along the entire medial edge of the shaft, and the nutrient foramen is found on this edge. The lateral lip of the intertubercular groove is stronger and longer.

Figure 9.7 **Humeral, ulnar, and radial growth.** The pairs of immature humeri (*left*), radii (*center*), and ulnae (*right*), shown here in anterior view, are from a one-year-old and a six-year-old. Natural size.

9.1.5 Humeral Measurements (Figure 9.8)

Measurements of the humerus are used for stature estimation, age estimation, sex determination, biomechanical load calculations, and other analyses.

1. **Maximum humeral length** (Martin, 1928: 1010, #1; Buikstra and Ubelaker, 1994: 80, #40): The maximum length that can be measured between the top of the humeral head and the most distant point on the distal humerus. Measured with an osteometric board.
2. **Humeral biomechanical length** (Trinkaus, et al., 1999: 756): The distance between the top of the humeral head and the distalmost point on the lateral lip of the trochlea. Measured with an osteometric board.
3. **Humeral bicondylar** (or **bi-epicondylar**) **breadth** (Martin, 1928: 1010–1011, #4; Buikstra and Ubelaker, 1994: 80, #41): With a sliding caliper, measure the greatest distance between the medial and lateral epicondyles, making sure to keep the jaws of the caliper parallel to the long axis of the humeral shaft.
4. **Humeral midshaft circumference** (Martin, 1928: 1011, #7a): Determine the location of midshaft (preferably using 50% of humeral biomechanical length) and use a flexible cloth tape to determine the minimum circumference at that location.

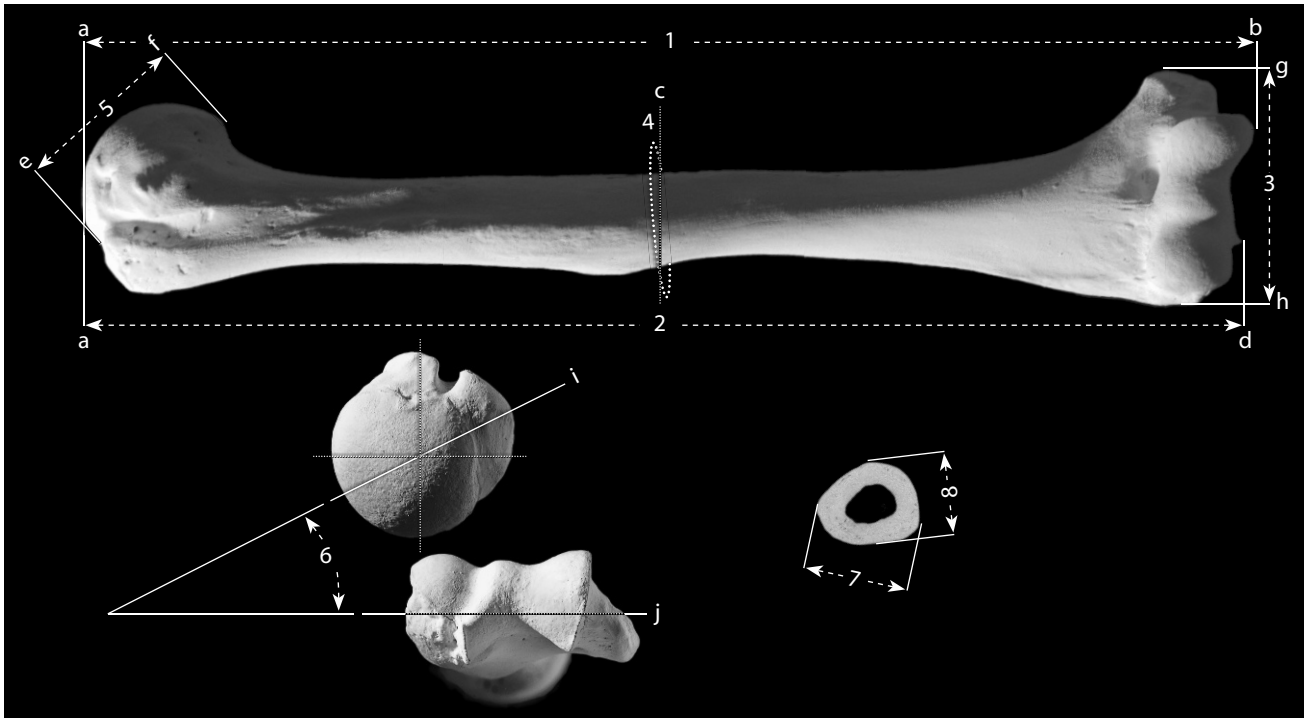

Figure 9.8 **Humeral measurements.** One-half natural size.

Locations: a) superiormost point of the head; b) point most distant from 'a', measured parallel to the shaft; c) 50% of '2'; d) distalmost point on lateral lip of trochlea; e) most lateral point of head ('e' and 'f' must be in the same paracoronal plane); f) most medial point of head (*ibid.*); g) medialmost point of medial epicondyle; h) lateralmost point of lateral epicondyle; i) midhumeral axis; j) distal articular axis.

Measurements: 1) maximum humeral length; 2) humeral biomechanical length; 3) humeral bicondylar (or epicondylar) breadth; 4) humeral midshaft circumference; 5) vertical head diameter; 6) humeral torsion; 7) maximum midshaft diameter (measured at 'c'); 8) minimum midshaft diameter (measured at 'c').

5. **Vertical head diameter** (Martin, 1928: 1011, #10; Buikstra and Ubelaker, 1994: 80, #42): Using a sliding caliper, measure the greatest distance between the margins of the head in a paracoronal plane.
6. **Humeral torsion** (Krahl and Evans, 1945; Larson, 2007): Position the humerus so that an imaginary line (the 'distal articular axis') drawn through the centers of the capitulum and the trochlea is parallel to the tabletop. Using a protractor or a torsiometer, measure the angle between the tabletop and the midhumeral axis (a line that divides the proximal articular surface into anterior and posterior halves and passes through the greater tubercle between the insertion sites of the *infraspinatus* and *supraspinatus muscles*).
7. **Maximum midshaft diameter** (Martin, 1928: 1011, #5; Buikstra and Ubelaker, 1994: 80, #43): Determine the location of midshaft (50% of humeral biomechanical length) and use a sliding caliper to determine the largest cross-sectional dimension at that point.
8. **Minimum midshaft diameter** (Martin, 1928: 1011, #6; Buikstra and Ubelaker, 1994: 80, #44): Use a sliding caliper to determine the smallest cross-sectional dimension at midshaft.

9.1.6 Humeral Nonmetric Traits

- **Septal aperture**: In about 2%–11% of individuals (more common in females than males: Mays, 2008), the bone separating the olecranon and coronoid fossae becomes so thin that an opening between the two fossae is formed, a septal aperture. Usually scored as 0 (absent), or 1 (present).
- **Supracondylar process** (or **supratrochlear spur**): About 5–7 cm above the medial epicondyle, on the medial supracondylar ridge, some individuals develop an inferomedial projection which serves to anchor the *ligament of Struthers.* The ligament connects this process with the medial epicondyle. Usually scored as 0 (absent), or 1 (present).

9.2 Radius (Figures 9.7, 9.9–9.15)

9.2.1 Anatomy

The radius is the shortest of the three arm bones. It is named for its action, a turning movement about the capitulum of the humerus, which allows the bone to rotate relative to the more fixed ulna. The radius articulates proximally with the humerus at the capitulum and medially with the ulna on both proximal and distal ends. Distally, the radius articulates with two carpal bones of the wrist: the lunate (medially) and the scaphoid (laterally).

a. The **radial head** is a round articular structure on the proximal end of the radius. It articulates, via its cupped proximal surface (**articular fovea** or **facet**), with the humeral capitulum, whereas the edge of the radial head (**articular circumference**) articulates with the radial notch of the ulna.
b. The **radial neck** is the slender segment of the radius between the head and the radial tuberosity.
c. The **radial** (or **bicipital**) **tuberosity** is a blunt, rugose, variably shaped structure on the anteromedial side of the proximal radius. It marks the insertion of the *biceps brachii muscle*, a flexor and weak medial rotator of the forearm, and a large *biceps bursa* that underlies this muscle.
d. The **shaft** (or **body**) of the radius is the long, thin section between the radial tuberosity

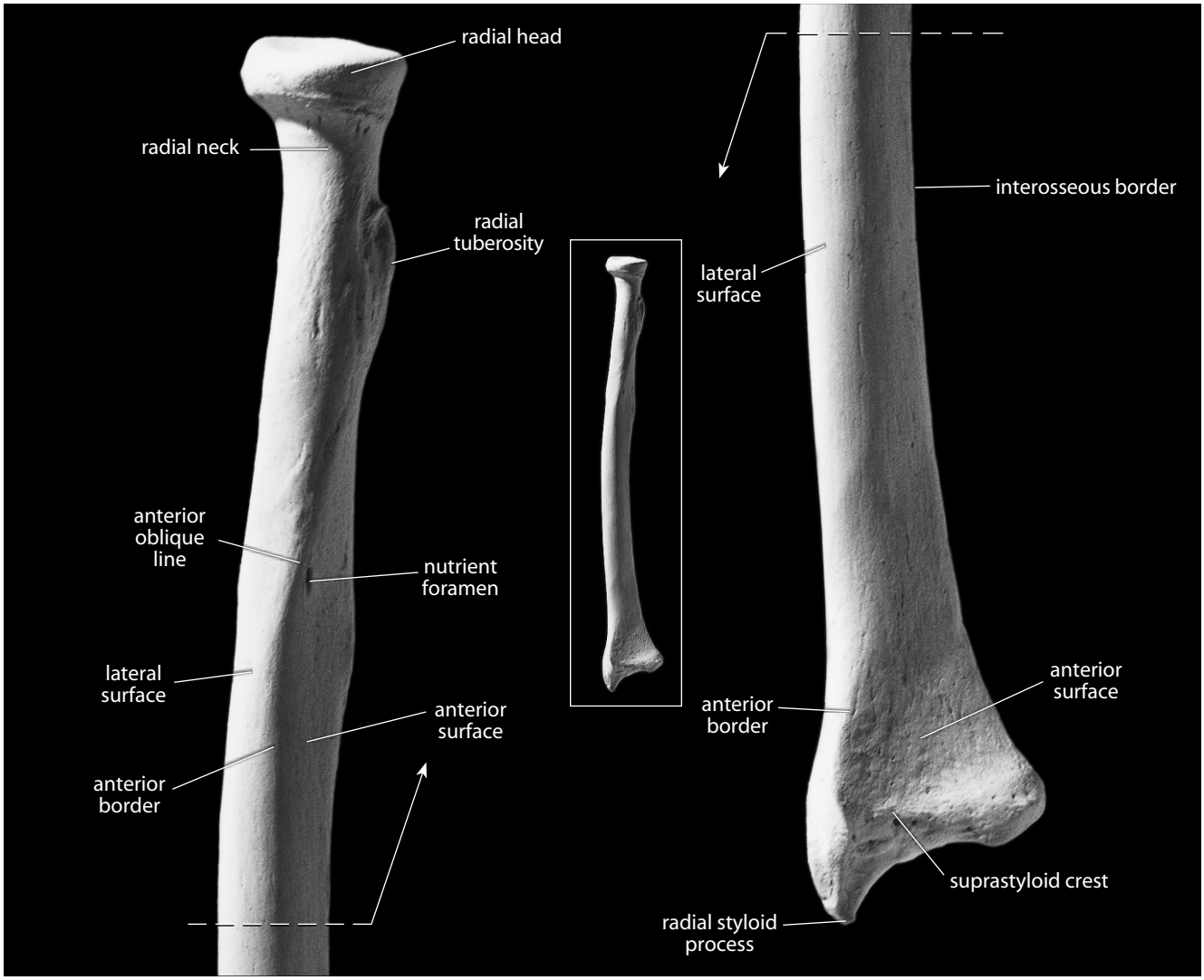

Figure 9.9 **Right radius, anterior.** *Left:* proximal portion; *right:* distal portion. Natural size.

and the expanded distal end. The shaft is divided into three named surfaces by three borders (or margins).

e. The **anterior surface** is the portion of the shaft surface between the anterior and interosseous borders. It is broadest distally.

f. The **posterior surface** lies between the posterior and interosseous borders.

g. The **lateral surface** is bounded by the anterior and posterior borders.

h. The **interosseous border** (or **crest**) is the sharp medial edge of the radial shaft. It serves as the attachment site for a fibrous membrane, the *interosseous membrane*, which divides the forearm into an anterior and a posterior compartment. These house and isolate the flexor and extensor groups of muscles that act across the wrist.

i. The **anterior border** is continuous with the anterior oblique line and extends distally to the suprastyloid crest.

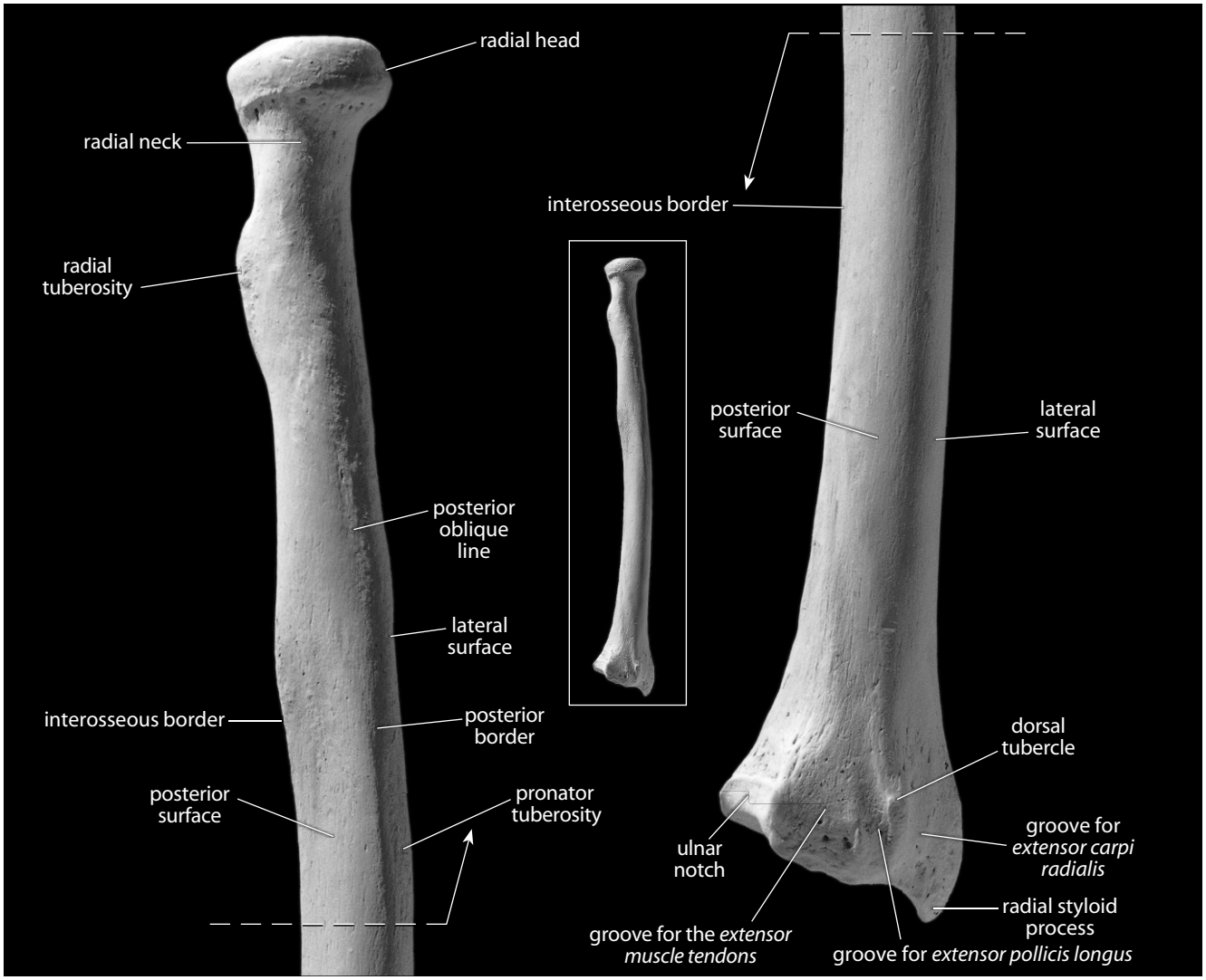

Figure 9.10 **Right radius, posterior.** *Left:* proximal portion; *right:* distal portion. Natural size.

j. The **posterior border** runs distally towards the dorsal tubercle.

k. The **nutrient foramen** exits the bone toward its distal end and is located on the anterior surface of the proximal half of the radius.

l. The **anterior oblique line** is on the anterior surface of the shaft. It spirals inferolaterally from its origin at the base of the radial tuberosity. This line gives origin to extrinsic muscles of the hand.

m. The **posterior oblique line** mirrors the more marked anterior oblique line, but on the posterior surface of the shaft. It spirals inferolaterally from the base of the radial tuberosity to the tuberosity for the *pronator teres muscle.*

n. The **pronator tuberosity** (or ***pronator teres* impression**) is a midshaft roughening on the lateral surface marking the site of insertion of the *pronator teres muscle*.

o. The **ulnar notch** is a concave articular hollow on the medial corner of the distal radius. It articulates with the distal end of the ulna.

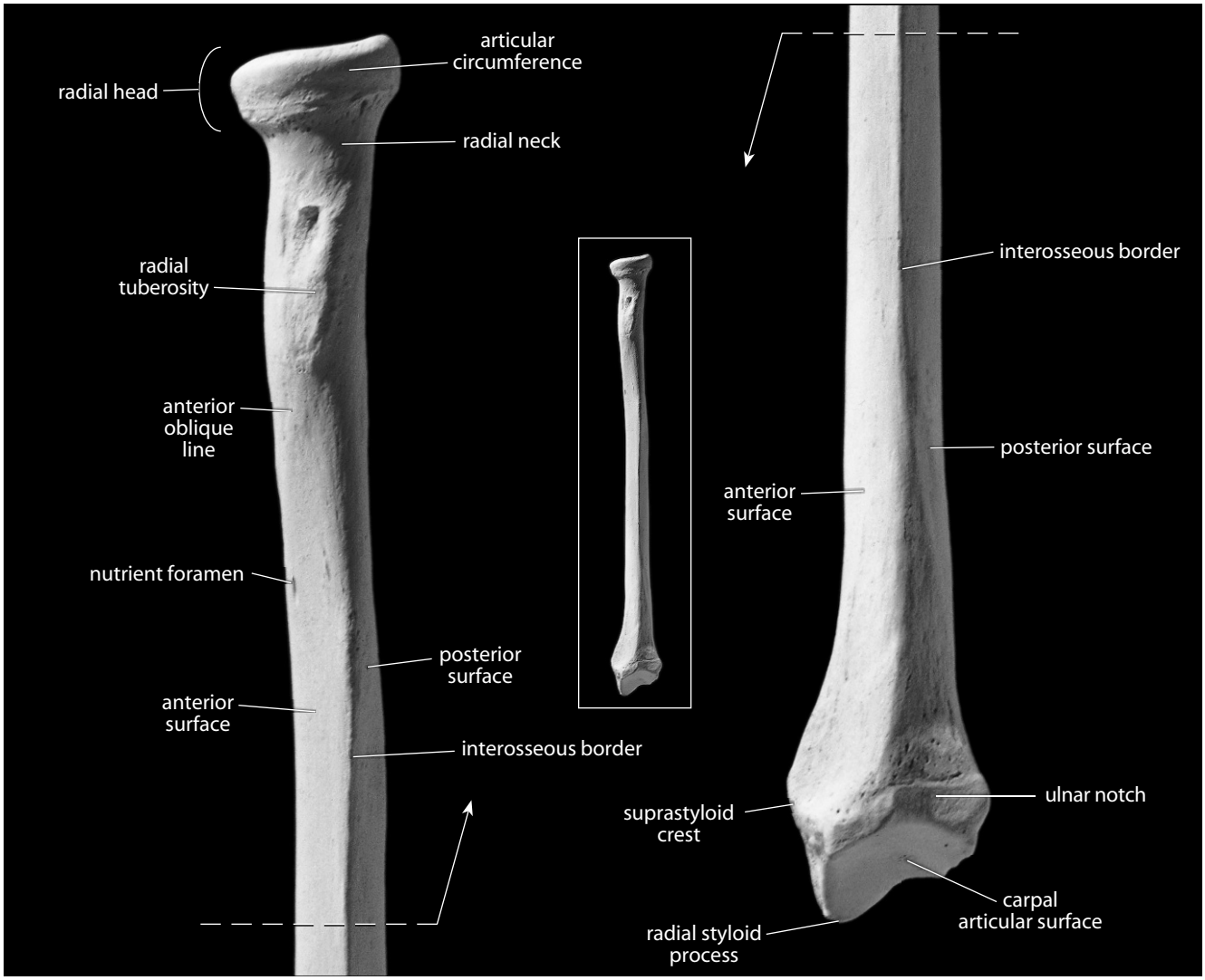

Figure 9.11 **Right radius, medial.** *Left:* proximal portion; *right:* distal portion. Natural size.

p. The **carpal** (or **distal radial**) **articular surface** articulates with carpal bones—the lunate on the medial side, and the scaphoid on the lateral side.

q. The **styloid process** is a sharp projection on the lateral side of the distal radius.

r. The **suprastyloid crest** runs obliquely above the styloid process on the anterior surface. It serves as the attachment site of the *brachioradialis muscle.*

s. The **dorsal** (or **Lister's**) **tubercle** is a large tuberosity on the posterior surface of the distal radius. The grooves between this and other tuberosities on the dorsum of the distal radius house the *tendons of extrinsic extensor muscles* of the hand.

t. The **groove for the *extensor muscle tendons*** is the broad depression on the medial side of the posterior surface of the distal radius.

u. The **groove for *extensor pollicis longus*** is immediately medial to the dorsal tubercle.

v. The **groove for *extensor carpi radialis*** is the hollowing lateral to the dorsal tubercle.

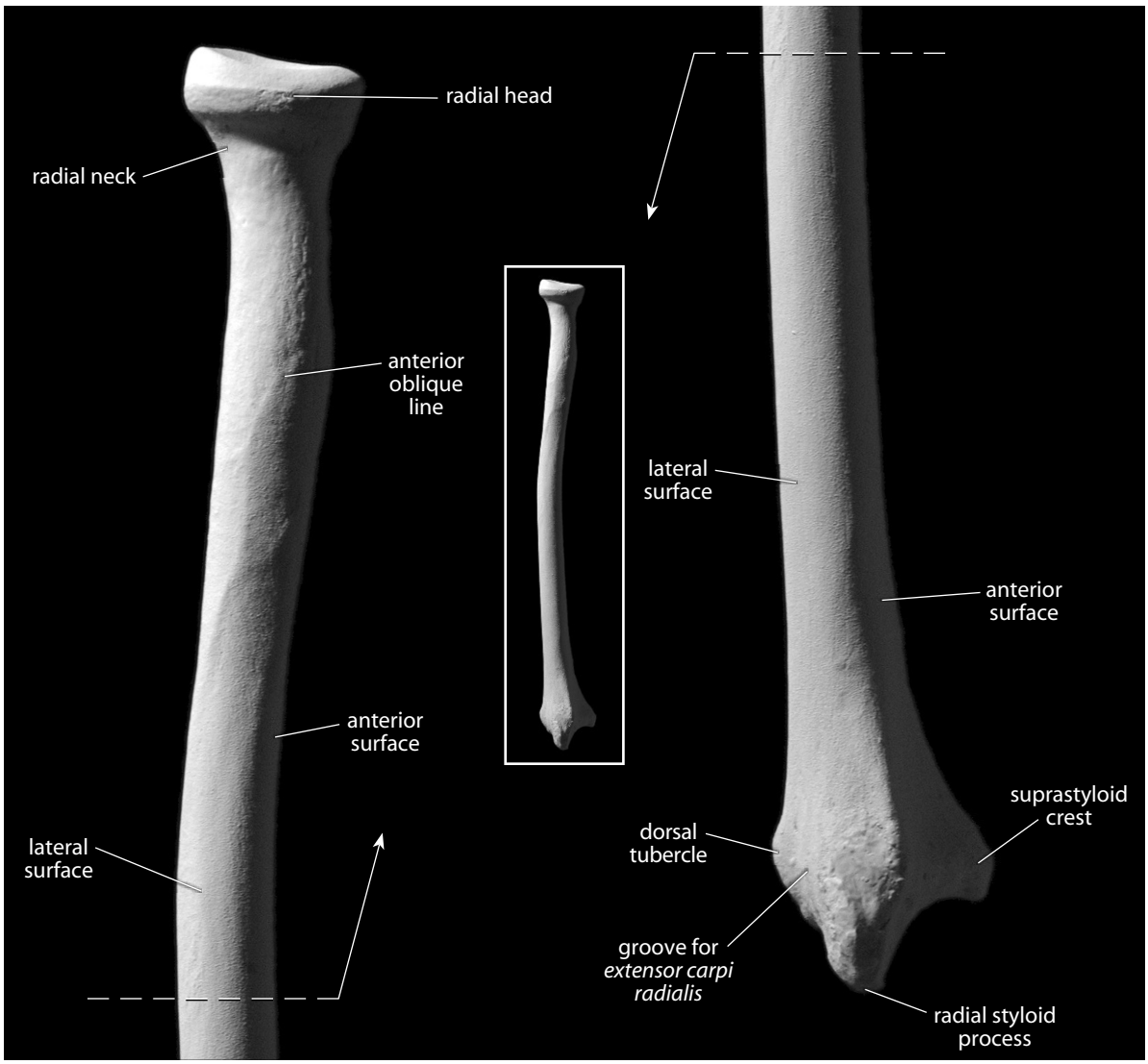

Figure 9.12 **Right radius, lateral.** *Left:* proximal portion; *right:* distal portion. Natural size.

9.2.2 Growth (Figure 9.7)

The radius ossifies from three centers: the shaft, the proximal epiphysis (head), and the distal epiphysis. The proximal epiphysis fuses first, beginning to fuse with the shaft at about 14–17 years in males, and about 11.5–13 years in females. The distal epiphysis begins to fuse slightly later: at about 16–20 years in males and at 14–17 years in females (Scheuer and Black, 2000).

9.2.3 Possible Confusion

Radial shaft segments might be mistaken for the ulna or fibula, and isolated distal ends might be mistaken for the clavicular notch of the manubrium, but the following features help identify fragments of the radius.

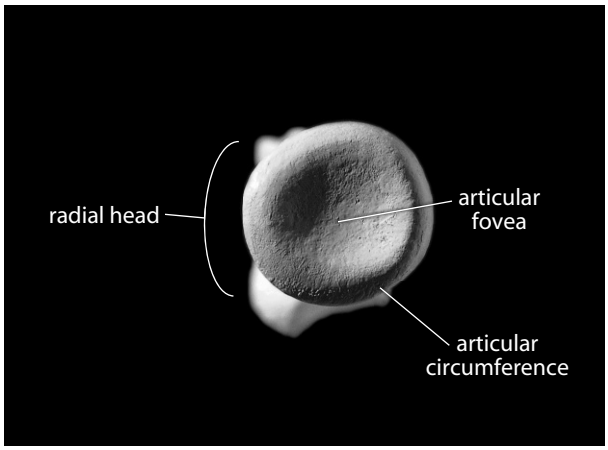

Figure 9.13 **Right radius, proximal.** Lateral is up, anterior is toward the left. Natural size.

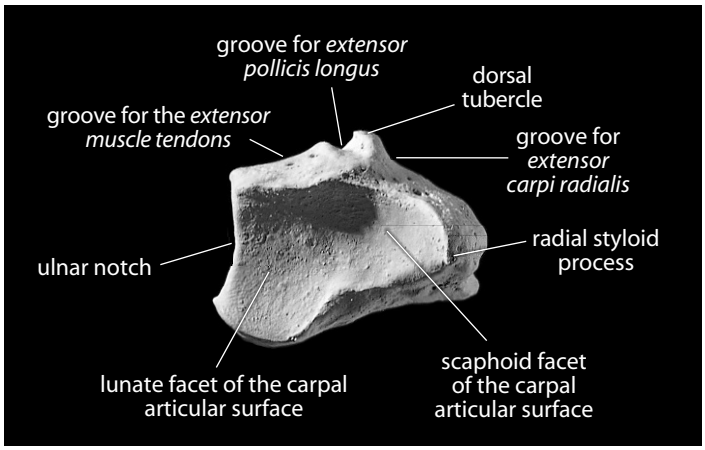

Figure 9.14 **Right radius, distal.** Dorsal is up, lateral is toward the right. Natural size.

- The ulnar shaft tapers continuously (the circumference decreases) from proximal to distal, whereas the radius does not (see cross sections in Chapter 14).
- The ulnar shaft has a sharp interosseous border, but the two other corners are not as evenly rounded as they are in the radius, which has a teardrop shape in cross section and a smoother, more uniform crest (see cross sections in Chapter 14).
- Most of the ulnar shaft is triangular (see cross sections in Chapter 14). The ulnar shaft only becomes round in cross section at its distal end. In contrast, the radial shaft is circular proximally and is a rounded triangle at midshaft. It is a broad, anteroposteriorly compressed oval with cortex that thins at more distal cross sections.
- The fibula, also a long slender bone with crests, is much more irregular in cross section and much longer than the radius (see cross sections in Chapter 14).
- The carpal (or distal radial) articulation has two discernible articular surfaces (or "facets," see Figure 9.14), whereas the clavicular notch of the manubrium has only a single articular facet.

9.2.4 Siding

- For an intact radius, the ulnar notch is medial, the radial tuberosity and interosseous border are medial, the dorsal tubercles are posterior, and the styloid process is lateral.
- For an isolated proximal end, the tuberosity faces anteromedially. The medial portion of the proximal ulnar articular surface has the greatest proximodistal dimension.
- There is a small ridge on the posteromedial aspect of the neck, congruent with the superior aspect of the medial edge of the radial tuberosity.
- For an isolated segment of shaft, the interosseous border is medial, and the oblique line is anterior. The nutrient foramen exits the bone distally and is situated anteriorly on the shaft. The posterolateral surface has the greatest rugosity at about midshaft.
- For an isolated distal end, the anterior surface is smooth and flat, the posterior surface has extensor grooves, the ulnar notch is medial, and the styloid process is lateral. The styloid process is smooth on its anterior surface.

9.2.5 Radial Measurements (Figure 9.15)

Measurements of the radius are used for stature estimation, age estimation, sex determination, biomechanical load calculations, and other analyses.

1. **Maximum radial length** (Martin, 1928: 1014, #1; Buikstra and Ubelaker, 1994: 80, #45): Place the head of the radius against the stationary end of an osteometric board and use the sliding plate to measure the maximum distance to the distalmost tip of the styloid process.
2. **Radial biomechanical length** (Trinkaus, et al., 1999: 756–757): Using a spreading caliper or a large sliding caliper with inside points, measure the distance between the center (deepest point) of the radial head and the deepest point of the carpal (or distal radial) articular surface.
3. **Radial head anteroposterior diameter** (Martin, 1928: 1015, #5(1)): Using a sliding caliper, determine and measure the largest diameter of the head of the radius.
4. **Radial midshaft circumference** (Martin, 1928: 1015, #5(5)): Determine the location of midshaft (preferably using 50% of radial biomechanical length) and use a flexible cloth tape to determine the minimum circumference at that location.
5. **Radial anteroposterior midshaft diameter** (Martin, 1928: 1015, #5a; Buikstra and Ubelaker, 1994: 80, #46): Determine the location of midshaft as above, and use a sliding caliper to measure the anteroposterior diameter at that location.
6. **Radial mediolateral** (or **transverse**) **midshaft diameter** (Martin, 1928: 1015, #4a; Buikstra and Ubelaker, 1994: 80, #47): Determine the location of mid- shaft as above, and use a sliding caliper to measure the mediolateral diameter at that location.

9.2.6 Radial Nonmetric Traits

- There are no commonly cited nonmetric traits of the radius.

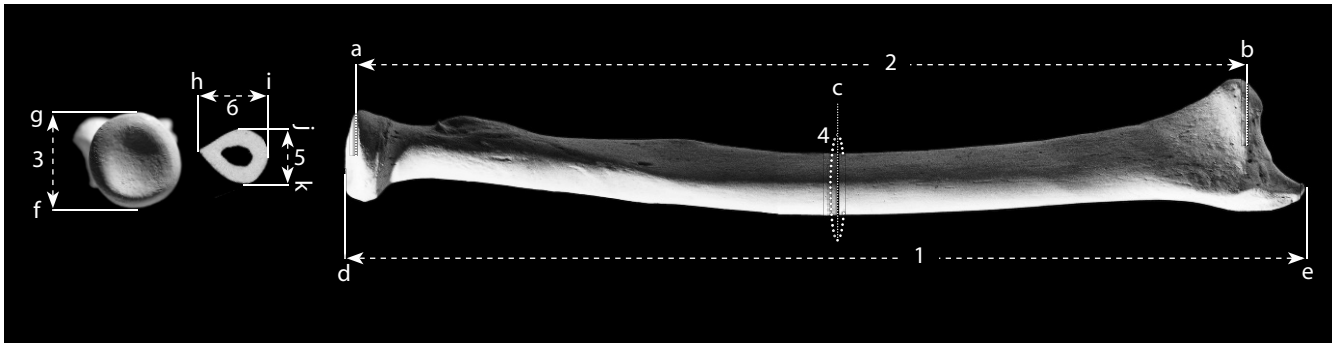

Figure 9.15 **Radial measurements.** One-half natural size.

Locations: a) deepest point of radial head; b) deepest point of distal articular surface; c) 50% of '2'; d) superiormost point on head; e) point on styloid process farthest from 'd'; f) posteriormost point on the articular circumference; g) anteriormost point on the articular circumference; h) medialmost point at midshaft; i) lateralmost point at midshaft; j) anteriormost point at midshaft; k) posteriormost point at midshaft.

Measurements: 1) maximum radial length; 2) radial biomechanical length; 3) radial head diameter; 4) radial midshaft circumference; 5) anteroposterior midshaft diameter (measured at 'c'); 6) mediolateral (or transverse) midshaft diameter (measured at 'c').

9.3 Ulna (Figures 9.7, 9.16–9.22)

9.3.1 Anatomy

The ulna is the longest, thinnest bone of the forearm. It articulates proximally with the trochlea of the humerus and with the head of the radius. Distally it articulates with the ulnar notch of the radius and with an articular disk that separates it from the carpal bones. This provides freer rotation of the hand and radius around the ulna than is seen in many other mammals.

a. The **olecranon** (previously the **olecranon process**) of the ulna is the most proximal part of the bone. It is a massive, blunt process. The *triceps brachii muscle*, the primary extensor of the forearm, has its insertion on the tuberosity of this process.

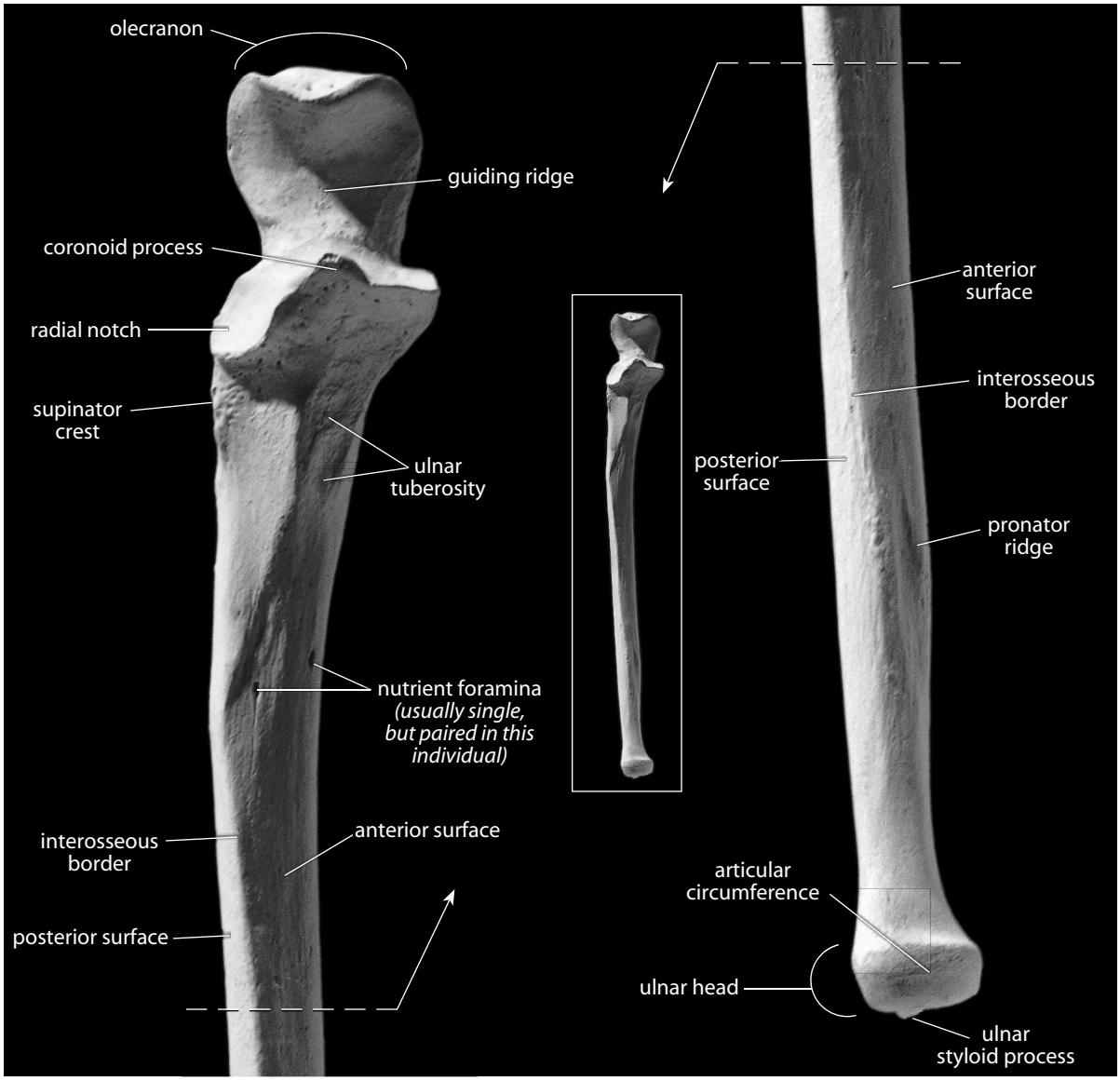

Figure 9.16 **Right ulna, anterior.** *Left:* proximal portion; *right:* distal portion. Natural size.

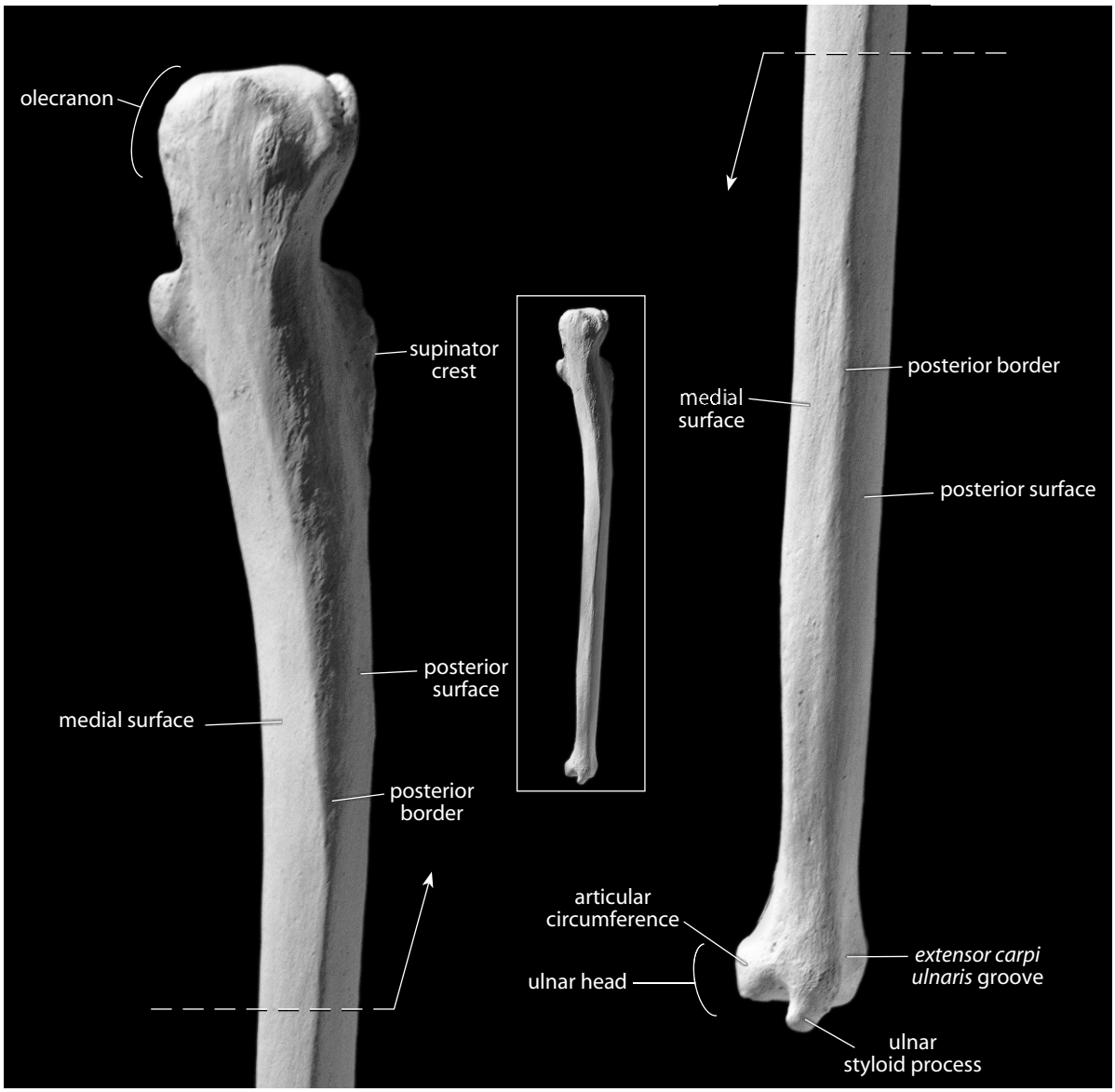

Figure 9.17 **Right ulna, posterior.** *Left:* proximal portion; *right:* distal portion. Natural size.

b. The **trochlear** (or **semilunar**) **notch** of the ulna articulates with the trochlear articular surface of the distal humerus. In contrast to the more mobile radius, rotary motion is very restricted at the ulnar part of the elbow joint, sharply limiting the ulna in its ability to rotate around its long axis.

c. The vertical **guiding ridge** separates the trochlear notch into medial and lateral portions.

d. The **coronoid process** is the anterior, beak-shaped projection at the base of the trochlear notch.

e. The **ulnar** (or **brachial**) **tuberosity** is a roughened depression immediately inferior to the coronoid process. It marks the insertion of the *brachialis muscle*, a flexor of the elbow that originates from the anterior surface of the humerus.

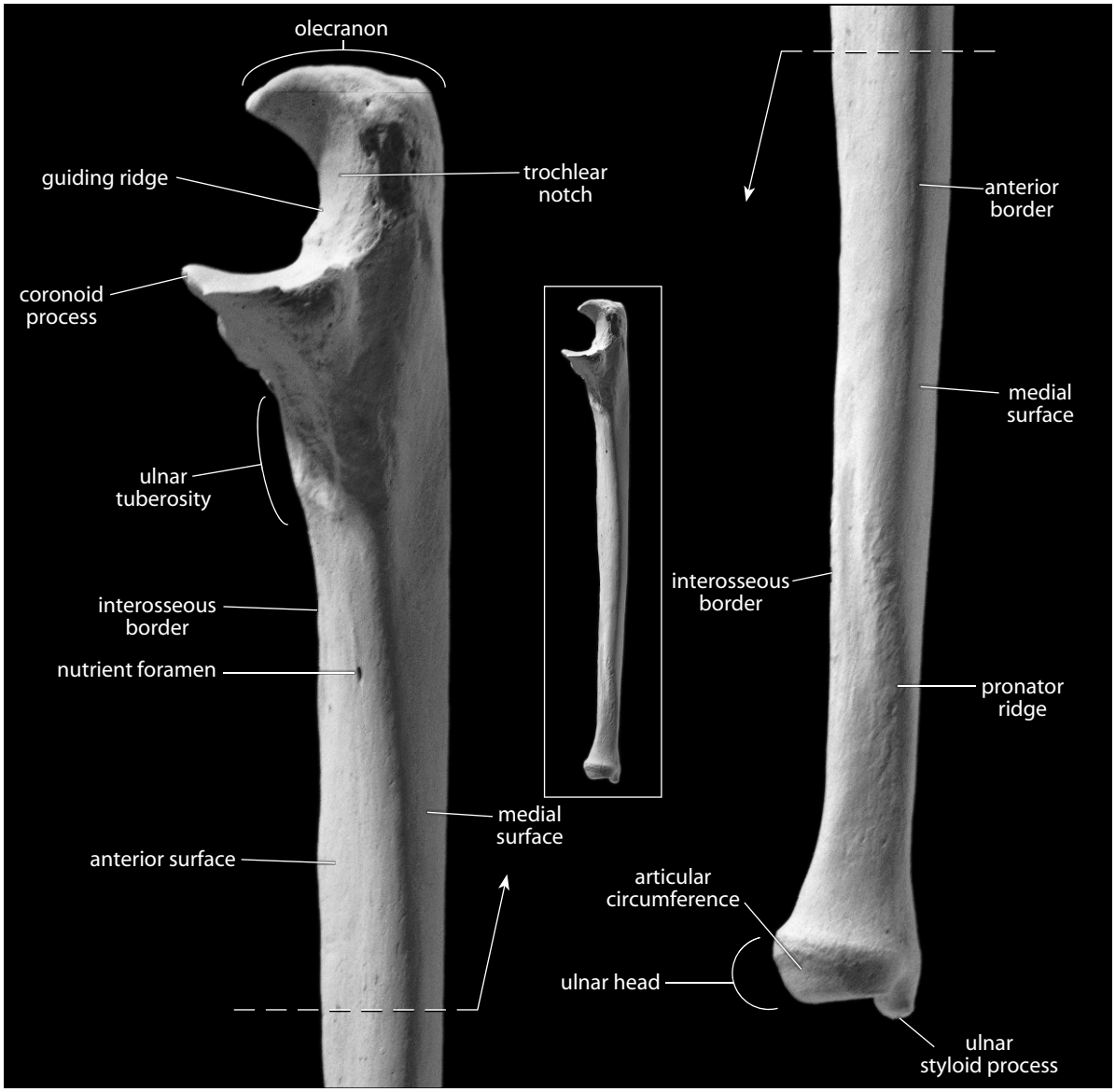

Figure 9.18 **Right ulna, medial.** *Left:* proximal portion; *right:* distal portion. Natural size.

f. The **radial notch** is the small articular surface for the radius. It is located along the lateral margin of the coronoid process.

g. The **shaft** (or **body**) is the long segment of bone between the brachial tuberosity and the inflated distal end of the ulna. The shaft is divided into three named surfaces by three borders (or margins).

h. The **anterior surface** is the portion of the shaft surface between the anterior and interosseous borders.

i. The **posterior surface** lies between the posterior and interosseous borders.

j. The **medial surface** is bounded by the anterior and posterior borders.

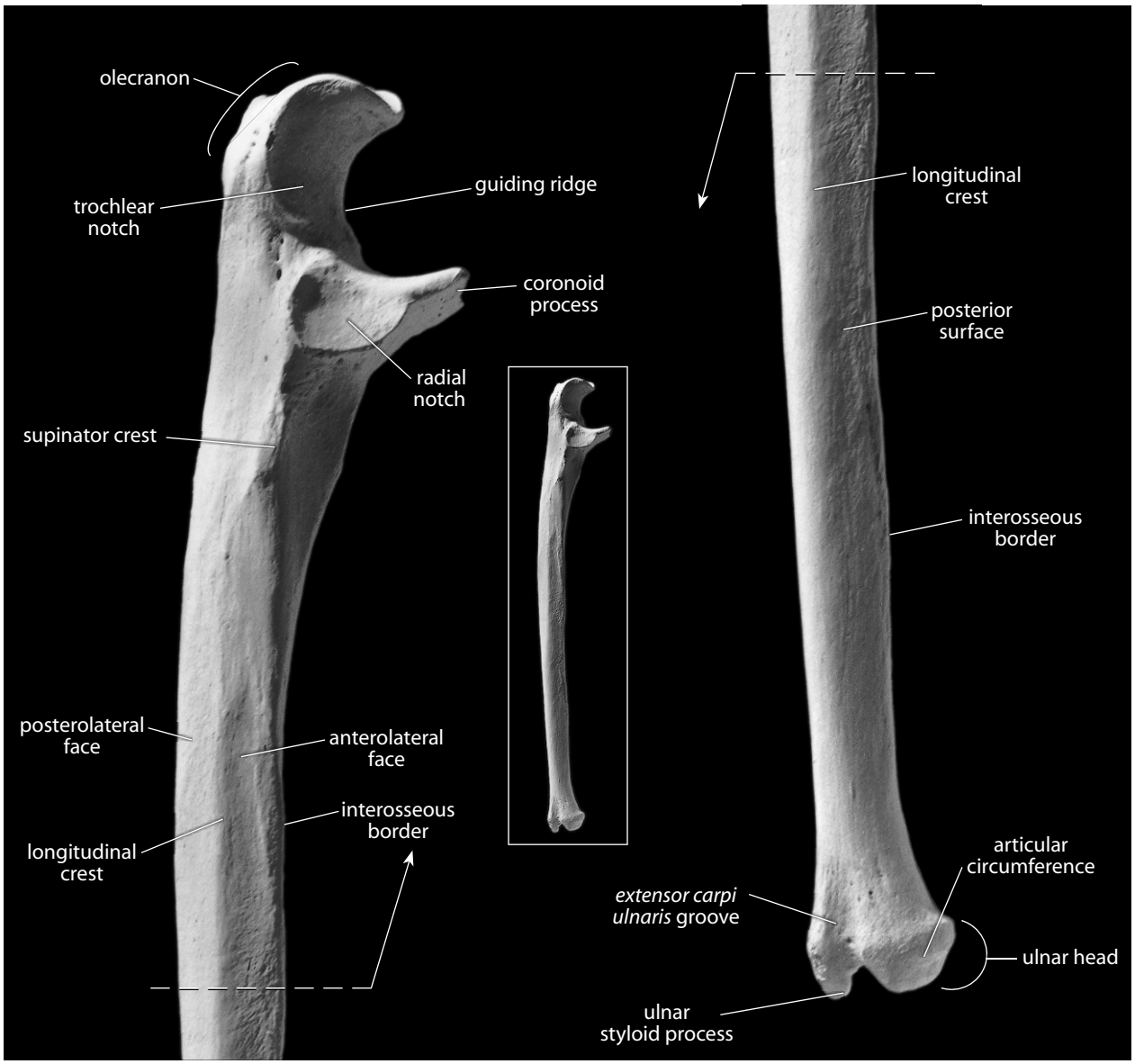

Figure 9.19 **Right ulna, lateral.** *Left:* proximal portion; *right:* distal portion. Natural size.

k. The **interosseous border** (or **crest**) is the sharpest border on the ulna. It lies opposite the radius, on the lateral aspect of the ulnar shaft between the anterior and posterior surfaces.

l. The **anterior** (or **medial**) **border** is thick and rounded, originating medial to the ulnar tuberosity and running along the anteromedial shaft. The distal one-third of the border angles posteriorly, and it terminates near the medial side of the styloid process.

m. The **posterior border** runs distally towards the styloid process.

n. The **longitudinal crest** divides the posterior surface into two portions: a posterolateral face and an anterolateral face.

o. The **nutrient foramen** exits the bone in a distal direction and is found on the anteromedial ulnar shaft.

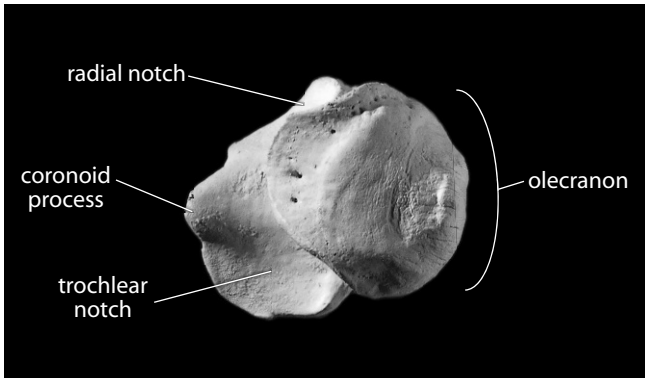

Figure 9.20 **Right ulna, proximal.** Lateral is up, anterior is towards the left. Natural size.

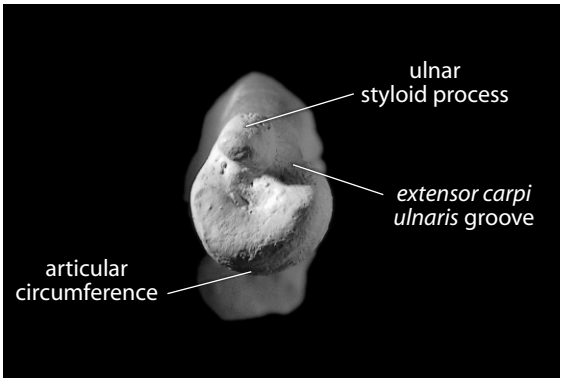

Figure 9.21 **Right ulna, distal.** Anterior is down, lateral is towards the right. Natural size.

p. The **supinator crest** is just superior to the interosseous border but with a more anterosuperior orientation. It serves as the origin for the *supinator muscle*.

q. The **pronator ridge** is a short, variably expressed ridge on the distal one-fourth of the shaft. It is located anteromedially and is the origin site for the *pronator quadratus muscle*.

r. The **ulnar head** is the enlarged distal end of the bone.

s. The **ulnar styloid process** is the sharp, distalmost projection of the ulna. It is set on the posteromedial corner of the bone. Its end gives attachment to the *ulnar collateral ligament* of the wrist. It is separated from the remainder of the head by a deep groove or pit, the **fovea**.

t. The ***extensor carpi ulnaris* groove** is adjacent to the styloid process, located proximolaterally to it. It houses the tendon of the *extensor carpi ulnaris muscle*, a dorsiflexor and adductor of the hand at the wrist.

u. The **articular circumference** (or **radial** or **circumferential articulation**) is the distal, lateral, round articulation that conforms to the ulnar notch of the radius in the same way that the radial head conforms to the radial notch of the proximal ulna.

9.3.2 Growth (Figure 9.7)

The ulna ossifies from three centers: the shaft, the proximal epiphysis (olecranon), and the distal epiphysis. The proximal epiphysis fuses first, beginning to fuse with the shaft at about 13–16 years in males, and about 12–14 years in females. The distal epiphysis begins to fuse slightly later: at about 17–20 years in males and at 14–15 years in females (Scheuer and Black, 2000).

9.3.3 Possible Confusion

The ulnar proximal and distal ends are diagnostic, but isolated shafts could be mistaken for radial or fibular shafts.

- The radial shaft is more triangular, or teardrop-shaped, in cross section. It has two rounded corners and one sharp corner. Radial shafts do not taper distally as the less regular ulnar shaft does (see cross sections in Chapter 14).

- The fibular shaft is much more irregular in cross section, with multiple sharp corners (see cross sections in Chapter 14).
- See the description of the radial shaft for further details.

9.3.4 Siding

- For an intact ulna, the olecranon is proximal and posterior, the radial notch is lateral, and the interosseous border is lateral.
- For an isolated proximal end, use the same criteria given earlier for an intact ulna. Note also that the brachial tuberosity is medially displaced.
- For an isolated shaft segment, the shaft tapers distally, and the nutrient foramen exits the bone distally and is located on the anterior shaft surface. The interosseous border is lateral. The shaft surface anterior to the crest is more hollowed proximally, but this may flatten distally. At midshaft and distally, the surface posterior to the interosseous border may display a narrow groove that is variable in expression.
- For an isolated distal end, the styloid process is posterior, and the groove for the *extensor carpi ulnaris* is lateral to the process.

9.3.5 Ulnar Measurements (Figure 9.22)

Measurements of the ulna are used for stature estimation, age estimation, sex determination, biomechanical load calculations, and other analyses.

1. **Maximum ulnar length** (Martin, 1928: 1017, #1; Buikstra and Ubelaker, 1994: 81, #48): Place the olecranon against the stationary end of an osteometric board and use the sliding plate to measure the maximum distance to the distalmost tip of the styloid process.

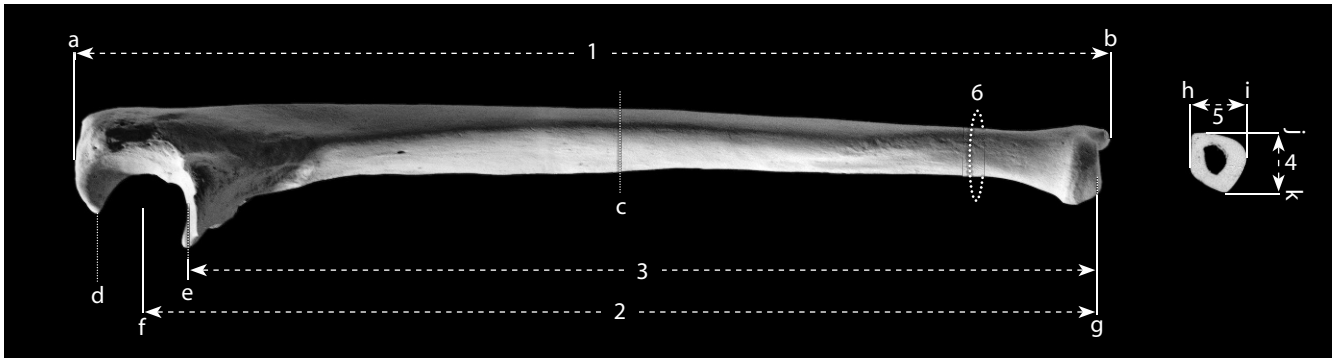

Figure 9.22 **Ulnar measurements.** One-half natural size.

Locations: a) superiormost tip of olecranon; b) point on the styloid process most distant from 'a'; c) midshaft (50% of '2'); d) most proximal point on trochlear surface; e) most distal point on trochlear surface; f) proximodistal midpoint of trochlear surface; g) deepest (most proximal) point on the distal surface of the ulnar head, excluding the *extensor carpi ulnaris* groove; h) lateralmost point at midshaft; i) medialmost point at midshaft; j) anteriormost point at midshaft; k) posteriormost point at midshaft.

Measurements: 1) maximum ulnar length; 2) ulnar biomechanical length; 3) ulnar physiological length; 4) maximum anteroposterior diameter (measured at 'c'); 5) maximum mediolateral (or transverse) diameter (measured at 'c'); 6) ulnar minimum circumference.

2. **Ulnar biomechanical length** (Trinkaus et al., 1999: 756): With a spreading caliper or a large sliding caliper, measure the distance between the proximodistal midpoint of the trochlear notch and the centerpoint of the distal head.
3. **Ulnar physiological length** (Martin, 1928: 1018, #2; Buikstra and Ubelaker, 1994: 81, #51): Using a large sliding caliper with inside points or a spreading caliper, place one tip of the caliper into the deepest (most distal) point of the trochlear notch, and measure the minimum distance to the deepest (most proximal) point on the ulnar head (excluding the *extensor carpi ulnaris* groove).
4. **Maximum anteroposterior diameter** (Martin, 1928: 1020, #11; Buikstra and Ubelaker, 1994: 81, #49): Determine the point along the shaft where the interosseous crest has its greatest development. Use a sliding caliper to measure the anteroposterior diameter at this point.
5. **Maximum mediolateral** (or **transverse**) **diameter** (Martin, 1928: 1020, #12; Buikstra and Ubelaker, 1994: 81, #50): Determine the point along the shaft where the interosseous crest has its greatest development. Use a sliding caliper to measure the mediolateral diameter at this point.
6. **Ulnar minimum circumference** (Martin, 1928: 1018, #3; Buikstra and Ubelaker, 1994: 81, #52): Use a flexible cloth tape to determine the minimum measurable circumference of the diaphysis (usually near the distal end of the shaft).

9.3.6 Ulnar Nonmetric Traits

- **Trochlear notch shape**: Examine the geometry of the articular surface(s) in the ulnar trochlear notch and characterize the shape of the surface(s) as being one of the following: 1 (continuous), 2 (hour-glass), 3 (discrete), 4 (indent), 5 (island), 6 (island and hour-glass), 7 (discrete and hour-glass), or 8 (indented and hour-glass).

9.4 Functional Aspects of the Elbow and Wrist

The elbow joint has a single joint capsule, but its three different bony elements operate differently within the capsule. The humeroulnar joint is a simple hinge, whereas the humeroradial joint is a pivot joint resembling a ball-and-socket joint. The proximal and distal radioulnar joints are mirror images, allowing the radius to spin during pronation and supination. The axis of rotation passes obliquely across the forearm through the proximal radius and distal ulna. The hand articulates with the forearm through the radiocarpal articulation at the wrist.

Actions of flexion and extension at the elbow joint are accomplished by contraction of two major antagonists, the *biceps brachii* (flexor) and *triceps brachii* (extensor). The former has two origins: the long head from the supraglenoid tubercle of the scapula (the tendon passes through the intertubercular groove of the humerus) and the short head from the tip of the scapular coracoid process. The insertion of this muscle on the radial tuberosity makes it a powerful flexor of the forearm at the elbow. It can also supinate the forearm. The *triceps brachii* is also a complex muscle, with three heads of origin: the long head from the infraglenoid tubercle of the scapula and the lateral and short heads from the posterior surface of the humeral shaft. This major extensor of the forearm at the elbow inserts on the olecranon of the ulna.

In addition to flexion and extension at the elbow, the unique articulation of the elbow allows for pronation and supination of the forearm. The *pronator teres muscle* originates from the medial epicondyle and medial supracondylar ridge of the humerus and inserts on the lateral radial shaft. Supination occurs when the *biceps brachii* works on the already pronated forearm. In addition, the *supinator muscle* originates on the lateral epicondyle of the humerus and the lateral surface of the

proximal ulna. It crosses to the anterior oblique line of the proximal radius, and its contraction thus causes supination.

Many muscles surround the radius and ulna. Most of these function via tendons to cause flexion and extension at the wrist and within the hand. Flexors are found in a compartment anterior to the radius and ulna, whereas extensors are located in a compartment posterior to these bones. These extrinsic hand muscles and their tendons can be easily palpated.